Thesis subject 2017

Laboratory : L’Institut Jean Le Rond d’Alembert

University: UPMC, CNRS

Title of the thesis: Spatial properties of interior acoustic sound fields: Combining physical, numerical, and perceptual studies in room acoustics

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Collaborations within the thesis: none

Program affiliation: none

Cotutelle: none

University : none

This subject can be published on the doctoral school’s web site: yes

Thesis’s summary (abstract):
The goal of this thesis project will be to extend significantly current acoustical objective and perceptual parameters to take into account the directional characteristics and spatial variations of the sound field in performance spaces. In order to accomplish this, the project entails developments in spatial room acoustic measurement techniques, psychoacoustics testing, and the development of perceptual models that link these aspects. This project has 3 main axes: high resolution spatial RIR measurement techniques, numerical simulations and scale model spatial RIR measurement techniques, and perceptual studies to develop improved spatial attributes for room acoustics assessment. It is expected that each of these axes will be developed in order to achieve the stated goals. Room impulse responses are usually measured with omnidirectional loudspeakers and microphones. Microphone arrays have been proposed for the measurement of so-called directional room impulse responses as well as loudspeaker arrays and directional loudspeakers. In parallel, scale models have remerged in the field of room acoustics, due to advances in ultrasonic transducers and acquisition devices. Development of directional source and receiver arrays will considerably improve the flexibility and power of scale model measurements for use in assessing objective and perceptive parameters. This project therefore aims at deriving perceptual descriptors based on various spatial measures and listening experiments.
Subject

(Present in 2 or 3 pages, in particular to the context, objectives, expected results)

Keywords
Room acoustics, spatial hearing, spatial impression, psychoacoustics, spatialized sound, 3d audio, acoustic scale models

Candidate profile
We are looking for dynamic, creative, and motivated candidates with scientific curiosity, strong problem solving skills, the ability to work independently and in a multidisciplinary team environment, and the desire to push their limits and areas of confidence to new areas of knowledge. The candidate must have a Master's degree in Acoustics, Architectural Acoustics, Applied Physics, or Digital Audio Signal Processing. A strong interest in room acoustics and perception is required. We do not expect the candidate to have all the necessary skills in this multidisciplinary subject, nevertheless a willingness and the ability to learn quickly in new areas is obligatory.

Theme:
Room acoustics

Context:
The scientific field of room acoustics was created at the end of the 19th century with Sabine’s formula for reverberation time. This parameter, describing the energy decay rate, was founded on many ideal assumptions of the space, source, receiver, and associated sound field. Since then, numerous additional parameters have been developed to quantify the temporal details of the energy decay, with all of these assuming omnidirectional source and receivers. Only 2 room acoustic parameters have been proposed which attempt to associate the spatial variations of the energy decay at the listener position. The Lateral-Energy Fraction (LEF) employs an additional dipole receiver oriented along the inter-aural axis of an assumed listener. The Inter-Aural Cross Correlation (IACC) compares the left and right ear signals using a dummy binaural head. Both measurements assume a receiver oriented towards a single source.

On the perceptual side, the existing acoustic parameters have their perceptive correlates, for which they were been developed to explain. In previous research at IRCAM, a set of mutually independent perceptual descriptors for the acoustic quality of concert halls has been developed (e.g., Jullien, 1995; Kahle and Jullien, 1994, 1995). It has been shown that these descriptors correlate well with some objective room acoustic criteria (Jullien, 1995); e.g., the temporally extended direct sound energy (DirE) descriptor, which controls the perceived presence of a sound source in a reverberant environment, agrees well with Lochner and Burger’s “energy ratio criterion” for speech intelligibility (Lochner, 1958). In order to control room effects along the relevant perceptual dimensions, most of the proposed descriptors require a temporal, spectral, and spatial weighting. However, these studies were carried out over 20 years ago, when the available measurement, synthesis, and sound rendering capabilities were far simpler than those available today. Alternative work has recently been carried out concerning coupled room acoustics, regarding both physical sounds fields and perceptual aspects (Luizard, 2014a,b, 2015a,b).

It is well accepted in the field of room acoustics that the existing measured parameters and perceptual attributes are adequate for understanding rather simple situations, and general use conditions. However, they are not sufficient to be able to separate a “good” performance hall from a “great” hall, and even less capable of assuring excellent acoustic quality prior to construction.

Objectives:
The goal of this thesis project will be to extend significantly current acoustical objective and perceptual parameters to take into account the directional characteristics and spatial variations of the sound field in performance spaces. In order to accomplish this, the project entails developments in spatial room acoustic measurement techniques, psychoacoustics testing, and the development perceptual models that link these aspects.

Room impulse responses are usually measured with omnidirectional loudspeakers and microphones. Microphone arrays have been proposed for the measurement of so-called directional room impulse responses (DRIRs; Balamages and
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Rafaely, 2004; Gover et al, 2004; Khaykin and Rafaely, 2012). DRIRs enable the S-T-F analysis of the incident sound field. Similarly, loudspeaker arrays and directional loudspeakers have been used for room acoustic analysis in order to radiate acoustic energy to some selected directions in space (Pueo et al, 2004; Tervo et al, 2009). Combining a spherical loudspeaker array (SLA) with a spherical microphone array (SMA) results in a so-called acoustic MIMO system (Morgenstern et al, 2016 2017) for room acoustic analysis, which in general adds a higher spatial resolution (i.e. spatial diversity) to the three-dimensional analysis of the incident sound field. In room acoustics auralization, the RIR, DRIRs, and MIMO-RIRs are directly applied to convolution-based reverberation processors. The S-T-F representation of DRIRs allows for a perceptual control of the reverberation process; MIMO-RIRs also allow for controlling the sound source directivity.

In parallel, scale models have remerged in the field of room acoustics, due to advances in ultrasonic transducers and acquisition devices. This tool allows for the investigation of sound fields in complex spaces that pose difficulties for computational methods. Development of directional source and receiver arrays will considerably improve the flexibility and power of scale model measurements for use in assessing objective and perceptive parameters.

This project therefore aims at deriving perceptual descriptors based on various spatial measures and listening experiments. Expected results:

This project has 3 main axes: high resolution spatial RIR measurement techniques, numerical simulations and scale model spatial RIR measurement techniques, and perceptual studies to develop improved spatial attributes for room acoustics assessment. It is expected that each of these axes will be developed in order to achieve the stated goals.

Bibliography:


Ecole doctorale SMAER  
Sciences Mécaniques, Acoustique, Electronique, Robotique


